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(54) Title: METHOD OF BLASTING

(57) Abstract: A method of blasting in which rock pile profile associated with a blast field is controlled by precise control of the detonation delay times between and/or within individual blastholes in the blast field, in combination with the control of one or more other blast parameters.

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## METHOD OF BLASTING

The present invention relates to a method of blasting using an adjustable, highly precise blasthole initiation system in combination with specific aspects of blast design to provide  
5 improved blast results, more specifically to control the rockpile (muckpile) profile associated with a blast.

Blasting operations produce rockpiles of material which is thrown (or displaced) by the blast. The characteristics of the rockpile profile (e.g. shape and displacement) produced  
10 influences the extent of excavation subsequently required, as well as the productivity of that excavation. It would be desirable to provide a method of blasting which allows the rockpile profile associated with a blast to be controlled and optimised, thereby allowing the efficiency associated with the blasting operation to be significantly enhanced by improved excavator productivity. It would also be desirable to control and tailor the particular  
15 rockpile profile associated with a blast to the mine excavation system associated with a particular blast site.

In accordance with the present invention it has now been found that these benefits may be achieved by precise control of certain aspects of blast design. More specifically, the  
20 present invention provides a method of blasting in which rockpile profile associated with a blast field is controlled by precise control of the initiation/detonation delay times between and/or within individual blastholes in the blast field, in addition to the control of one or more other important blast parameters, in particular the blasthole geometry, explosive charge and blast initiation location. This approach is fundamentally different from  
25 conventional blasting techniques which neither provide the adjustable delay times and high precision required nor generally vary the blasthole geometry, explosive charge and/or blast initiation location over a blast field specifically for the purpose of controlling the rockpile profile. In conventional blasting techniques most blasthole characteristics are generally designed to be constant over the entire blast field, or over large sections of the blast field. It  
30 has now been found that particular combinations of delay times, using highly precise initiation systems, and one or more of blast geometry, explosive charge and blast initiation

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location, applied as required differentially to various parts of the blast field, enable tailoring of the muckpile.

In accordance with the present invention precise control of blast delay time means control  
5 within a tolerance of less than one millisecond of the required and intended delay time  
between adjacent blastholes and/or within individual blastholes. This degree of control  
may be achieved using an electronic initiation system, as opposed to conventionally used  
non-electronic initiation systems. In one aspect of the invention it has been found that  
10 electronic initiation systems allow highly precise control of the delay between and/or  
within individual blasthole firings over the blast field and, in turn, this provides enhanced  
flexibility with respect to blast design such that the benefits of the present invention may  
be achieved. In addition, these systems are programmable and so provide the capability to  
obtain the required delay times, as opposed to conventional systems, which generally have  
a limited range of fixed delay times.

15

Typically, in accordance with the present invention the blast field is made up of a number  
of blastholes, and the invention resides in controlling the characteristics of the blastholes,  
particularly the blasthole diameter, geometry and explosive charge contained, in  
combination with precise control of the detonation delay between and/or within the  
20 blastholes. In the following the invention will be illustrated by reference to this kind of  
blast field. It has been found that precise control of the delay between blasthole firings  
allows the effect of other aspects of blast design on rockpile profile to be manipulated and  
optimised. Any one or more of the blasthole characteristics may be employed in  
combination with precise firing delay control in order to achieve the desired rockpile in a  
25 given situation.

In accordance with the present invention it is possible to control the magnitude of  
displacement of the rockpile in a particular direction and in selected zones of the blast to  
achieve a desired rockpile profile. Thus, the profile may be flattened or displaced forwards  
30 in certain areas or, alternatively, made to heave upwards or be minimally displaced in other  
areas as required to suit the mine excavation system. These possibilities are achieved in

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accordance with the present invention by designing the blast based on a high level of precision of control, as made available for example by the use of an electronic initiation system, in addition to the use of specific blast parameters.

- 5 Enhancement (increase) of rockpile displacement in a desired direction may be achieved by manipulating the inter-hole delay between blastholes, as well as the in-hole initiation within specific blast geometries. In accordance with the present invention these delays are controlled with great precision by using an adjustable, highly precise initiation system such as an electronic initiation system. Specific blast geometries to enhance the rockpile
- 10 displacement in a particular direction include the use of an optimised blasthole pattern which is preferably a staggered pattern such that the ratio of inter-hole spacing along rows of blastholes (where the rows are taken to be perpendicular to the direction of required displacement) to the perpendicular distance between rows is in the range 1:2 to 3:2 and, preferably, in the range 7:10 to 6:5. Most preferably the ratio is in the range 7:10 to 1:1.
- 15 The rows are preferably drilled parallel to any pre-existing or newly-created free faces in the blast field which are perpendicular to the desired direction of displacement. The blasthole orientation may also be manipulated to enhance rockpile displacement. In this embodiment the blastholes are generally inclined with the hole toe upwards in the same direction as the required displacement at an acute angle to the vertical, typically in the
- 20 range up to 45 degrees. The explosive masses and energies within the blastholes may also be manipulated to control rockpile displacement. Usually, for maximum displacement the explosive masses and energies are maximised within the constraints of local environmental considerations, such as the avoidance of excessive vibration or overpressure levels and hazardous rock ejections.

25

- Within such blast geometries, the displacement in a desired direction may be increased by the use of highly precise short inter-hole delays along rows of blastholes (where the rows are generally perpendicular to the desired direction of displacement). Specifically the inter-hole delays are typically from 0 to 4ms per metre of inter-hole spacing (where the
- 30 spacing is defined as the hole separation in such rows). The precise delay interval chosen may depend upon factors such as rock type and condition, and blast geometry. In a

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preferred embodiment the inter-hole delays are from 0 to 2ms per metre of inter-hole spacing for most rock types. The specific inter-hole delay chosen from this range is the shortest delay possible that does not provide excessive vibration or blast damage. Use of a highly precise delay system, such as an electronic initiation system, allows these delays to  
5 be controlled to within a tolerance of less than one millisecond.

A further aspect of the invention for regions where muckpile displacement is to be enhanced is to use two or more such high precision initiators within each blasthole with a delay of two milliseconds or less, preferably zero, between them. Preferably one of these  
10 initiators is located close to the bottom, or toe, of the blasthole and the others are located further up the explosive column at regular intervals.

In addition, it has been found that rockpile displacement in the direction perpendicular to the rows is enhanced by the use of selected ratios of time delay between rows of holes (the  
15 inter-row delay) to the delay between holes along a row (the inter-hole or intra-row delay). Typically, this ratio will be in excess of 5:1 and, preferably, in excess of 25:1.

The inter-hole delay time per metre of blasthole spacing is usually constant along each row, but may be varied, even between any pair of holes. The inter-row delay time per  
20 metre of rockpile burden may be kept constant or varied from row to row according to the muckpile profile required. The position of the primary initiator within blastholes and the delay between in-hole initiators within blastholes may also vary throughout the blast, according to the muckpile profile required.

25 In another embodiment of the invention, in order to provide a particular rockpile profile suited to a mine excavation method, the design features mentioned above may be employed in areas of the blast where a flatter rockpile profile is required, or increased displacement in the desired direction. Conversely, in areas of the blast where a steeper profile is required, or decreased displacement in a selected direction, this is achieved by  
30 quite different manipulations of the delay between and/or within blastholes within different specific designs of blast geometry, explosive charge and/or blast initiation location.

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Specific blast geometries to reduce the displacement in a particular direction include using a blasting pattern which preferably has larger spacing and burden distances than that used in areas where increased displacement is required. A similar effect may also be achieved by using as small a blasthole as possible while maintaining adequate rock fragmentation

5 for subsequent mechanical excavation. The blasthole diameter may be reduced from that used in areas where increased displacement is required. The orientation of the blastholes may also have an influence on the displacement observed. Thus, in areas where reduced displacement is required the blastholes may be inclined at reduced angles to the vertical when compared with those areas in which increased displacement is required. The

10 blastholes may be inclined at acute angles to the vertical as shallow as possible, including being angled away from the blast free face, while still effecting adequate rock fragmentation for excavation. The explosive masses and energies may be reduced to provide reduced displacement when compared with those areas in which increased displacement is required. The minimum explosive mass and energy must be used to effect

15 sufficient rock fragmentation for subsequent mechanical excavation. Within such blast geometries, the displacement in a particular direction may be decreased by the use of inter-hole delays along rows of holes greater than the inter-hole delays along rows where increased displacement is required. Typically, for areas requiring reduced displacement the inter-hole delay will be in the range 4 to 40ms, for example 20 to 40ms, per metre of

20 inter-hole spacing. The preferred delay between holes in these areas is the longest delay that does not result in problematic disruption of later firing blastholes.

In addition, displacement may be decreased further by using a ratio of delays between rows of holes (the inter-row delay) to the delays between holes along a row (the inter-hole or

25 intra-row delay) which is lower than the corresponding ratio for areas in which increased displacement is required. Typically, for decreased displacement this ratio is in the range of 5:1 or less. The blast, or region of the blast where reduced displacement is required, may also be initiated at locations distant from any pre-existing free faces, hence initiating the blast, or region of the blast, from the back towards the front. Multiple blast initiation

30 locations may thus be used, in contrast to conventional practice, which seldom uses more than one blast initiation location.

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A particular refinement of the method of the invention, especially for use in areas where the full displacement of the rockpile is to be maximised, such as in cast blasting, without causing environmental problems such as excessive overpressure is to use longer inter-hole delays, preferably greater than 4ms per metre of blasthole spacing in all or part of the front  
5 (or first firing) one or two rows and reverting to high precision shorter inter-hole delays (as specified above in the range 0 to 4 ms per metre of inter-hole spacing) in the latter part of the row or in subsequent rows.

Practical applications of the present invention include maximising the extent of material  
10 cast (or "thrown") to a final spoil position whilst simultaneously minimising the amount of material required to be rehandled by the excavator in producing interim platforms or surfaces from which to operate for further excavation. This enables the total amount of material to be handled by the excavator to be minimised, particularly in dragline operations. Such muckpile profiles may be optimally achieved through the application of  
15 differential blast design throughout the blast field as described herein.

In accordance with the present invention, the overall displacement of the rockpile in the final direction of spoil may also be increased to increase the overall productivity of excavation by decreasing the distance through which material is moved by the excavator.  
20 The invention may also be used to provide flatter, more spread out rockpiles for improving front-end loader productivity. Conversely, the invention may be used to provide steeper or taller rockpiles for improving productivity of certain equipment such as face shovels, or for increasing the rockpile voidage to enable easier digging. The invention may also be used to limit rockpile displacement in ore mines to enable improved ore/waste delineation and  
25 to maximise the concentration of ore recovered from the blast. The excavation process may also be enhanced by providing rockpiles in which a desired portion of the rockpile is located to provide easy equipment access while simultaneously providing an increased extent of material cast to final spoil in other parts of the rockpile.

30 Throughout this specification and the claims which follow, unless the context requires otherwise, the word "comprise", and variations such as "comprises" and "comprising", will

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be understood to imply the inclusion of a stated integer or step or group of integers or steps but not the exclusion of any other integer or step or group of integers or steps.



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THE CLAIMS DEFINING THE INVENTION ARE AS FOLLOWS:

1. A method of blasting in which rockpile profile of a blast field is tailored by control of rockpile displacement over the blast field as a result of blasting, this control being  
5 achieved by precise control of detonation delay times between and/or within individual blastholes in the blast field in combination with the control of one or more other blast parameters.
2. A method according to claim 1, wherein the one or more blast parameters are  
10 blasthole geometry, explosive charge and blast initiation location.
3. A method according to claim 1, wherein detonation delay times are controlled within a tolerance of less than one millisecond of the required and intended delay time.
- 15 4. A method according to claim 1, wherein the detonation delay times are controlled using an electronic initiation system.
5. A method according to claim 4, wherein the electronic initiation system is programmable.  
20
6. A method according to claim 1, wherein rockpile displacement in a desired direction is controlled by manipulating the inter-hole detonation delay between blastholes and/or the inter-row detonation delay between rows of blastholes.
- 25 7. A method according to claim 1, wherein rockpile displacement in a particular direction is increased by use of a blasthole pattern in which the blastholes are staggered such that the ratio of inter-hole spacing along rows of blastholes (where the rows are taken to be perpendicular to the desired direction of displacement) to perpendicular distance between rows is in the range 1:2 to 3:2.
- 30 8. A method according to claim 7, wherein rows of blastholes are drilled parallel to

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any pre-existing or newly-created free faces in the blast field which are perpendicular to the desired direction of rockpile displacement.

9. A method according to claim 1, wherein the blastholes are generally inclined with  
5 the hole toe upwards in the same direction as the desired rockpile displacement and at an acute angle to the vertical.

10. A method according to claim 7, wherein the displacement in a desired direction is increased by the use of inter-hole detonation delays along rows of blastholes (where the  
10 rows are generally perpendicular to the desired direction of displacement) of from 0 to 4ms per metre of inter-hole spacing (where the spacing is defined as the hole separation in such rows).

11. A method according to claim 5, wherein rockpile displacement is increased by use  
15 of two or more electronic initiators within each blasthole with a delay between each system of two milliseconds or less.

12. A method according to claim 11, wherein one of the initiators is located close to the  
20 toe of the blasthole and other initiators are located further up the blasthole at regular intervals.

13. A method according to claim 1, wherein rockpile displacement in a direction perpendicular to a row of blastholes is increased by use of selected ratios of detonation delay time between rows of holes (the inter-row delay) to the detonation delay time  
25 between holes along a row (the inter-hole delay), this ratio being in excess of 5:1.

14. A method according to claim 1, wherein rockpile displacement is decreased by using a ratio of detonation delay time between rows of holes (the inter-row delay) to the detonation delay time between holes along a row (the inter-hole or intra-row delay) which  
30 is lower than the corresponding ratio for areas in which increased displacement is required.

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15. A method according to claim 14, wherein the ratio is in the range of 5:1 or less.
16. A method according to claim 1, in which rockpile displacement in a blast field comprising at least three rows of blastholes is maximised without causing environmental  
5 problems by use of inter-hole detonation delay times of greater than 4ms per metre of blasthole spacing in all or part of the front one or two rows and by use of inter-hole detonation delay times in the range 0 to 4 ms per metre of inter-hole spacing in a latter part of the row or subsequent rows of blastholes.
- 10 17. A method according to claim 1, wherein a combination of detonation delay time and one or more blast parameters selected from blast geometry, explosive charge and blast initiation location are applied differentially over different parts of the blast field.
18. A method according to claim 1, wherein rockpile displacement in a particular  
15 direction is increased by use of a blasthole pattern in which the blastholes are staggered such that the ratio of inter-hole spacing along rows of blastholes (where the rows are taken to be perpendicular to the desired direction of displacement) to perpendicular distance between rows is in the range 1:2 to 3:2, by use of inter-hole detonation delays along rows of blastholes of from 0 to 4ms per metre of inter-hole spacing (where the spacing is  
20 defined as the hole separation in such rows), and by use of selected ratios of detonation delay time between rows of holes (the inter-row delay) to the detonation delay time between holes along a row (the inter-hole delay), this ratio being in excess of 5:1.
19. A method according to claim 18, wherein rockpile displacement in a particular  
25 direction is increased by use also of two or more electronic initiators within each blasthole with a delay between each initiator of two milliseconds or less.
20. A method according to claim 1, wherein rockpile displacement in a particular  
30 direction is decreased by use of a blasthole pattern in which the blastholes are staggered such that the ratio of inter-hole spacing along rows of blastholes (where the rows are taken to be perpendicular to the desired direction of displacement) to perpendicular distance

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between rows is in the range 1:2 to 3:2, by use of inter-hole detonation delays along rows of blastholes of from 4 to 40ms per metre of inter-hole spacing (where the spacing is defined as the hole separation in such rows), and by use of selected ratios of detonation delay time between rows of holes (the inter-row delay) to the detonation delay time  
5 between holes along a row (the inter-hole delay), this ratio being 5:1 or less.

21. A method according to claim 1, wherein rockpile displacement is controlled by precise control of detonation delay times between and/or within individual blastholes in a blast field in combination with control of at least one blast parameter selected from  
10 blasthole diameter, blasthole orientation, explosive mass, explosive energy and inter-hole detonation delay.

22. A method according to claim 21, wherein the blasthole diameter is reduced to produce decreased rockpile displacement.  
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23. A method according to claim 21, wherein the blasthole is inclined at a reduced angle to the vertical to produce decreased rockpile displacement.

24. A method according to claim 23, wherein the blasthole is angled away from a free  
20 face in the blast field.

25. A method according to claim 21, wherein the explosive mass is reduced to produce decreased rockpile displacement.

26. A method according to claim 21, wherein the explosive energy is reduced to produce decreased rockpile displacement.  
25

27. A method according to claim 21, wherein the rockpile displacement in a particular direction is decreased by use of inter-hole detonation delays along rows of blastholes  
30 greater than the inter-hole detonation delays along rows where increased displacement is required.

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28. A method according to claim 27, wherein the inter-hole detonation delay is in the range 4 to 40ms per metre of inter-hole spacing to produce decreased rockpile displacement.

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29. A method according to claim 21, wherein rockpile displacement is controlled by blast initiation location, reduced rockpile displacement being achieved by blast initiation distant from any pre-existing free faces in the blast field.

10 30. A method according to claim 29, wherein reduced rockpile displacement is achieved by blast initiation from the back towards the front of the blast field.

31. A method according to claim 21, wherein the blasthole diameter is increased to produce increased rockpile displacement.

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32. A method according to claim 21, wherein the blasthole is inclined at an increased angle to the vertical to produce increased rockpile displacement.

33. A method according to claim 21, wherein the explosive mass is increased to  
20 produce increased rockpile displacement.

34. A method according to claim 21, wherein the explosive energy is increased to produce increased rockpile displacement.

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU02/00054

**A. CLASSIFICATION OF SUBJECT MATTER**Int. Cl. <sup>7</sup>: F42D 1/055, 3/04

According to International Patent Classification (IPC) or to both national classification and IPC

**B. FIELDS SEARCHED**

Minimum documentation searched (classification system followed by classification symbols)

Refer electronic data base consulted below.

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

AU: IPC F42D 1/055, 1/06, 3/04

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

DWPI: IPC E21C, F42D with keywords such as blast, method, field, delay and similar terms.

**C. DOCUMENTS CONSIDERED TO BE RELEVANT**

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
X	AU 200028890 A (ROBOTH VERTRIEBSGESELLSCHAFT mbH) 26 October 2000 Whole document	1-34
Y	Whole document	1-34
P, Y	AU 200053560 A (BLAST DESIGN INTERNATIONAL, INC.) 15 March 2001 Pages 2-15	1-34
X	AU 46309/99 A (HATOREX AG) 24 January 2000 Whole document	1-6, 13-18, 21-34

☒ Further documents are listed in the continuation of Box C
 ☒ See patent family annex

* Special categories of cited documents:	
"A" document defining the general state of the art which is not considered to be of particular relevance	"T" later document published after the international filing date or priority date and not in conflict with the application but cited to understand the principle or theory underlying the invention
"E" earlier application or patent but published on or after the international filing date	"X" document of particular relevance; the claimed invention cannot be considered novel or cannot be considered to involve an inventive step when the document is taken alone
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"O" document referring to an oral disclosure, use, exhibition or other means	"&" document member of the same patent family
"P" document published prior to the international filing date but later than the priority date claimed	

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## INTERNATIONAL SEARCH REPORT

International application No.

PCT/AU02/00054

C (Continuation). DOCUMENTS CONSIDERED TO BE RELEVANT		
Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	US 4725991 A (CRENWELGE, Jr. et al) 16 February 1988	
A	Derwent Abstract Accession No. 87-197101-28, Class Q79, SU 1205643 A, (SKOCHINSKII MINING INST) 15 December 1986	

International application No.  
**PCT/AU02/00054**

This Annex lists the known "A" publication level patent family members relating to the patent documents cited in the above-mentioned international search report. The Australian Patent Office is in no way liable for these particulars which are merely given for the purpose of information.

Patent Document Cited in Search Report				Patent Family Member			
AU	200028990	EP	1046879				
AU	20053560	NONE					
AU	46309/99	BR	9906590	EP	1009967	WO	00/02005
		ZA	200000699				
US	4725991	NONE					